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RESPONSIBILITY FOR ACCIDENTS: RELEVANT RESULTS SELECTED FROM THE DRAG MODEL

by

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ABSTRACT

We provide a primarily qualitative summary of a selected number of results obtained for the Province of Quebec with the DRAG model of the Demand for Road use, Accidents and their Gravity. The selection, made on the basis of potential interest for the establishment of responsibility for road accidents, may also have relevance for general accident analysis and prevention.

Key-words: road accidents, injuries, fatalities, DRAG model, automobile insurance, pregnancy, alcohol

RÉSUMÉ

Nous faisons un résumé surtout qualitatif de résultats choisis de DRAG, un modèle explicatif de la Demande Routière, des Accidents et de leur Gravité appliqué au Québec. Le choix est dicté par l'intérêt éventuel des résultats pour établir la responsabilité en cas d'accident de la route mais peut s'avérer pertinent pour l'analyse des accidents en général ou leur prévention.

Mots-clés: accidents de la route, blessés, tués, modèle DRAG, assurance automobile, grossesse, alcool

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1. FOCUS: THE EXPECTED CONSEQUENCES OF VARIOUS FACTORS

In this paper, we ask questions about the expected consequences for road safety of various states of individual drivers or of their environment because the answers may be useful in establishing responsibility, in the sense of assigning liability or of determining fault. By road safety, we mean both the occurrence of accidents and their severity. States of the environment are defined by economic or physical factors; individual states consist of biological, physiological, legal or socioeconomic determinants.

Expected consequences of variables considered are described summarily, without the due care required of reports on econometric model estimates: the original reports on the DRAG model [1,2] contain detailed numerical values and permit a full appreciation of the statistical significance of the selected results. The model, based on monthly data for the Province of Quebec as a whole between December 1956 and December 1982, takes into account a larger number of factors than those mentioned here.[1]

Our estimates of expected consequences implicitly define a "representative individual". Since the features of this representative individual are drawn from data that are aggregate in nature--as in most economic models--they are limited by the intrinsic characteristics of these data. Some of the newest DRAG results, on pregnancy and alcohol for instance, will certainly benefit from further work, perhaps with disaggregate data: they are simply listed here, along with a few long established results, as first-round results of ongoing research.

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[1] According to Jack Carr and Samuel Rea of The University of Toronto, it is the most extensive modeling effort ever made to explain accidents and their severity.

2. REPORTING FORMAT

In Table 1, we distinguish between D, the direct effect of a factor, or effect obtained holding road use constant, and its indirect effect I due to variations in road use; the letter O denotes effects that arise through variations in other variables than road use and T the total effect of the factor in question. The dependent variables are: (i) road use, measured by gasoline[2] sales (gas); (ii) accidents with only property damage (mat), with at least one injury and no death (n-f), fatal accidents (fa), and the total number of accidents (acc); (iii) two measures of severity: the morbidity (mbc) and mortality (mtc) rates of accidents with bodily damage; (iv) finally, the number of injuries (inj), fatalities (fat), and their total (vic). All columns indicate the sign associated with an increase in the factor considered. The last three columns also present elasticities, defined as the ratio of the percentage change in the dependent variable to that of the explanatory factor; in the case of qualitative explanatory variables (underlined twice), the elasticity expresses the percentage change in the dependent variable due to the presence of the qualitative factor. A star denotes a t-statistic of the underlying regression coefficient larger than 2.00; t-statistics are not presented for the Column Acc results on the total number of accidents (because they are computed from results for the three components), or for the last three columns (because they contain information derived from accident level and severity rate estimates of previous columns). All results are drawn from the reference model or its variants in [1], except estimates of the effect of the Road Victim Compensation Act of 1961 and of age that come from unpublished work on a variant of the reference model. Now consider each factor in turn.

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[2] Results for diesel sales are not shown. Neither are results for the sum of accidents with injuries (non fatal) and fatal accidents.

Table 1. DIRECT, INDIRECT, AND TOTAL EFFECTS OF SELECTED DRAG MODEL FACTORS

		road use	accidents				severity		victims		
Dependent variable:		gas	mat	n-f	fa	acc	mbc	mtc	inj	fat	vic
a. Price of maintenance	D	+	-*	-*	-*	-	-	-	-.80	-1.02	-.80
b. Prop. of cars with belt	D	+*	+*	+*	+	+	+	-*	.22	-.01	.21
	I								.09	.19	.09
Speed limit + belt use	D	-	+	-	-	+	+	+	-.05	-.03	-.05
	I								.00	-.00	.00
c. Warmer/colder th. Sept.	D	+*	+*	+	-*	+	+*	-*	.04	-.05	.04
Rain	D	-	+*	+	-	+	+	-	.01	.00	.01
	I								-.00	-.01	-.01
Snow	D	+	+*	+	+	+	-	-	.00	-.01	.00
d. Unemployment	D	-*	-*	-	-*	-	-*	-	-.17	-.19	-.17
e. Road victim comp.Act'61	D	+	.26*	+*	+	+	-*	-*	.10	.02	.10
	I		.04						.02	.05	.02
	T		.30						.12	.07	.12
Auto insurance Act'78	D	+	.09	+*	+	+	-	-*	.25	.04	.24
	I		.03						.02	.03	.02
(Other factors)	O		-.02						-.01	.03	-.01
	T		.10						.26	.10	.25
f. Age risk index	D	+	3.88*	+	+*	+	+	+*	.81	7.95	1.05
Proportion fem. drivers	D	+	+	+	+	+	-	-	+	+	+
Pregnancy, all months	D	-	+	-	-	+	+	-	-	-	-
Pregnancy, 1st month	D	-	+	-	+	+	+	-	.06	-.15	.06
Pregnancy, 2nd month	D	-	+	+	+*	+	-	+	.31	.65	.32
g. Weekly hours worked	D		-*	+	+	-	+	+	+	+	+
Drug consumption	D	-	+	+*	+	+	+	-	+	+	+
Alcohol consumption	D	-	+	-	-	+	+	-*	.01	-.42	-.00
	I								-.01	-.03	-.02
	T								.00	-.45	-.02
Alcohol, spirits	D	-	+	+	-	+	+	-	.05	-.12	.04
Alcohol, wine	D	+	-	-	-	-	-	-	-.04	-.10	-.04
Alcohol, beer	D	+	-	-	+	-	+	+	-.07	.00	-.06
Alcohol, cider	D	-	+	+	+	+	-	-	.00	-.02	.00

gas: gasoline sales; mat: accidents with material damage only; n-f: non fatal accidents; fa: fatal accidents; acc: accident total; mbc: morbidity of accidents with corporal damage (injuries/(n-f + fa)); mtc: mortality of accidents with corporal damage (fatalities/(n-f + fa)); inj: injuries; fat: fatalities; vic: victims (injuries + fatalities).

3. ENVIRONMENTAL STATES

A. Prices: the cost of maintaining a vehicle

Increases in the cost of maintaining vehicles, an index of maintenance and insurance prices, yield decreased accident levels, severity rates and numbers of victims. This suggests that higher insurance prices and higher repair costs reduce maintenance (thereby increasing gasoline consumption--a result also found in Germany [3]) and increase driving care (probably reducing speeds). Consequently, **having a poorly maintained vehicle does not constitute *prima facie* evidence of negligence** because it says nothing about compensatory behaviour; similarly, forcing consumers to meet certain maintenance standards might increase the number of victims.

B. Vehicles: seat belt availability and use

Holding road use constant, the increased availability of seat belts increased all categories of accidents and the morbidity rate but reduced the mortality rate sufficiently to leave the number of fatalities essentially unchanged. However, increased gasoline sales imply indirect increases in road use (no doubt in speeds) and in all categories of victims. This suggests that freely wearing seat and shoulder belts leads to compensatory behaviour or increased speeds. **Wearing one's belt does not therefore constitute *prima facie* evidence of careful driving**; it may of course be wise protection.

The obligation to wear seat belts, combined with reduced speed limits, reduced the number of victims, but it is not possible to identify the effect of each law. They jointly reduced the frequency of accidents with bodily damage (in contrast with accidents with property damage only that increased) more than they increased the average severity of remaining accidents.

C. Infrastructure: the weather --temperature, rain, and snow

Weather that is uncomfortable (warmer or colder than the average for September), increases the total number of accidents but involves a substitution between fatalities and injuries[3]. Rain and snow also increase the total number of accidents but have no significant effect on the number of injuries and fatalities because of very small or offsetting changes in the number of accidents with bodily damage or in their severity. All weather variables therefore reveal the presence of substitution between numbers of accidents and their severity. Driving in uncomfortable or bad weather cannot therefore contitute by itself a presumption of imprudence because drivers are expected to make compensating adjustments.

4. INDIVIDUAL STATES

D. Employment status

The reduced road use associated with unemployment in Table 1 represents reductions in activities other than work and shopping activities (accounted for elsewhere in the model). The direct effect indicates that, holding road use constant, unemployment reduces all accident levels, their severity, and consequently injuries and fatalities. We conjecture that unemployment reduces the value of time and presumably speed and creates a presumption to that effect.

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[3] The implicit trade associated with uncomfortable weather is 22 injuries per fatality.

E. Insurance status

- Compulsory insurance: the Road Victim Compensation Act of 1961

The Road Victim Compensation Act of 1961 imposed liability insurance by (a) requiring drivers to carry a minimum amount of third party liability insurance and (b) by making insurance companies unconditionally responsible for claims up to that amount against individuals that were uninsured, insolvent or insured with companies that had failed; the mechanism for this was a compensation fund financed by the companies. The law also (c) threatened uninsured individuals involved in an accident or having committed an infraction with the removal of driving privileges and (d) tightened accident reporting procedures by the police. The obligation to carry insurance increased the proportion of insured vehicles approximately from 70% to only 85% despite the risk of losing one's driving license and car registration.

As a result of the law, all categories of accidents increased (by 30%, 15% and 17% respectively for mat., n-f and fa in Table 1) and their average severity was reduced, but not sufficiently to leave the number of victims unchanged: injuries and fatalities increased both directly and indirectly (the total effects were 12% and 7%, respectively). Formally, this result of the law of 1961 can be said to incorporate four elements: (i) a reporting effect due to stricter police procedures. This effect was of course limited because it is absent from reported deaths and cannot account for the increased gasoline consumption that is evidence of increased driving and/or speeds; (ii) the moral hazard effect due to the 15% of the market that bought insurance because of the obligation to ensure and due to the remaining 15% of the market--consisting of uninsured and uninsurable (to say nothing about the insolvent)--

that were suddenly insured often for free[4] through the compensation fund. If old barns burn more often when they are freely insured, what should one expect if insurance is compulsory? and when it is free? Forcing consumers to hold insurance and subsidizing the bad risks apparently reduced incentives to prudence. This may well be the most important part of the total effect effect of the law because it pertains to about 30% of the market. It is hard to say whether the impact occurred more through the 15% of insurable individuals who suddenly bought insurance and became new riders or through the remaining 15% who maintained their officially uninsured status but whose third-party minimum obligation was generally covered by others, a process which effectively often turned them into free riders; (iii) the adverse selection effect that may have occurred if the free insurance given to the the uninsurable (and to the uninsured and the insolvent) increased their number more than the risk of losing driving rights reduced it; (iv) a fourth effect came from court decisions that reestablished in part or in full the driving rights lost by truly free riders after an accident or infraction: this in fact introduced no-fault by court order for the worst of the free riders.[5]

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[4] But uninsured drivers whose license was suspended after an accident could settle with the Compensation Fund, obtain a certificate of solvency, and restore their permit. This amounted to a pay-as-you-hit scheme for them.

[5] We have not studied individual court decisions to that effect. Generally speaking, one expects the average uninsured individual to be a very bad risk because that category contains a large proportion of uninsurable cases with above average accident frequency and traffic infraction records. It has recently been shown in [4] that past accident involvement, infractions (and license suspensions for criminal offences) are significant predictors of accident probability. Such individuals were therefore more likely than others to be uninsurable, to have accidents and commit infractions, to lose their driving privileges and to want to recover them through court interference. Conversations with Provincial Police officers on this point have suggested that it would not be very hard to prove that uninsured individuals who obtained favourable decisions from courts were disproportionately bad risks. The Solomon instinct to establish responsibility sometimes loses to the Robin Hood instinct to redistribute it.

- No-fault-for-bodily-damage: the Automobile Act of 1978

We have analyzed elsewhere [5] in details the various effects of the Automobile Act of 1978 and will only summarize the argumentation here. Simple before-and-after visual analysis of the data suggests that the new régime increased the total number of reported accidents by 27% (a number consistent with an increase in the frequency of claims *per vehicle* of 20% experienced by insurance companies). The components of that total increased as follows: accidents with material damage only of more than $200-$250 by 26%, accidents with at least one injury by 32% and fatal accidents by 7%. Actual injuries increased by 31% and fatalities by 6%.[6] DRAG controls for a host of other factors that changed at the same time and imputes[7] to the new régime comparable increases in the number of victims but smaller increases in the number of accidents with property damage only, as one can see in Table 1. There, a distinction is made between the direct and indirect effects associated with the qualitative change brought about by the new régime and the *other-factors* effect due to modifications in the *average price of insurance*, in the *number of drivers* and in the *number of cars* caused by the Act.

The main effects occur through qualitative change and cover four elements: (i) a reporting effect, or moral hazard after-the-fact, due to faster compensation from insurers for material damage and a more favourable compensation from a state-subsidized centralized no-fault system for bodily damage. This potential exaggeration of claims explains none of the increase in

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[6] On a calendar year basis, fatalities increased from 1556 to 1765 (13.43%) in Quebec as they fell from 3697 to 3664 (0.89%) in the rest of Canada between 1977 and 1978.

[7] On the same basis as that used to obtain visual estimates, estimates based on DRAG results are not 10%, 26% and 10%, as in Table 1, but 7%, 24% and 9%.

fatalities or in road use and is therefore of limited interest, notably in view of the following three effects that all imply reduced driving care; (ii) a moral hazard effect due to the fact that the hard-core 15% of uninsured vehicles were forced by administrative rules to buy insurance. Proof of purchase of a minimum amount of third-party material damage liability coverage was requested with the vehicle registration application and registration fees included compulsory flat-rate bodily damage insurance. It became almost impossible not to insure a vehicle. The (partly) free riders were forced to pay for much more insurance than they might previously have been getting for nothing from the Compensation Fund: in particular, their own bodily damage was now covered, and the specific risk of license suspension did not apply. One would expect this forced increase in insurance consumption imposed on 15% of the market to decrease driving care significantly, as had occurred with the 1961 law that had done the first half of the job of forcing everyone to hold insurance; (iii) an adverse selection effect due to the flat-premium rating system for bodily damage, independent from the driver's safety record. This removed the link between performance and the most expensive part of insurance for bad risks: the premium for bodily damage. Flat rating created a subsidy for bad risks that increased with the risk level: the total price of insurance decreased proportionately more for the worst risk classes. In particular, this favored men and young drivers whose representation among driving license holders increased out-of-trend. The evidence for these increases suggests that the strength of the adverse selection effect is significant; (iv) a no-fault effect due to the fact that the notion of fault was removed for bodily damage. The strength of the other effects and the fact that the notion of fault was maintained for material damage suggest that this effect is very small, if it exists at all.

F. Biological status

- Age

There is no doubt that risk, defined as accidents per trip or per kilometer, is a U-shaped function of age that decreases until the age of about 40-45 and rises thereafter. On average, age as such is a factor of quality or performance. We have recently constructed a risk index of Quebec drivers that peaks in 1980 at a level 15.2% higher that at the beginning of the series in December 1956. As the preliminary estimates shown in Table 1 indicate, higher values of the index imply more accidents and more severe accidents, and the elasticities are high. One can compute the influence of changes in the age structure of drivers, holding everything else constant. For instance, the lower driving age since July 1962 (16 instead of 18 years of age) added on average[8] approximately 26,500 drivers to the average total number of drivers between 1962 and 1982: this increased the risk index by about 2.13% (or 30% of its average degradation[9]) and implied, taking direct and indirect effects roughly into account, 12% more accidents with material damage, 4% more injuries and 24% more fatalities.[10]

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[8] Trend analysis suggests that the new law created about 6,000 young drivers at the beginning (or 15% of the 16-19 year-old that accounted for 3.1% of all drivers); this number had reached 20,000 in 1972 (or 20% of the 16-19 year-old that accounted for 4.7% of all drivers) and 60,000 in 1982 (or 30% of the 16-19 year-old that accounted for 6% of all drivers).

[9] We are using half of the total 15% degradation as reference.

[10] The comparable values for the total effect, measured with a dummy variable, are 15%, 13% and 43%.

- Sex

The problem is not whether women have on average more accidents than men: they do not. The question is whether they have more accidents per trip or per kilometer. DRAG results rather suggest that they do, and that those accidents are less severe than men's, but not enough to offset the higher frequency: in consequence, increases in the proportion of female drivers increase the number of victims.

- Pregnancy

Conclusion 29 in [1, p. 180] is, in so far as we know, completely new:

> "[Whether one holds road use constant or allows for its variation,] there are good reasons to believe that pregnancy increases the frequency of accidents with material damage only and reduces the frequency of accidents with bodily damage and the number of victims. However, there are important differences between the second month of pregnancy, during which there are more accidents of all categories and more victims, and the other months."

Other analyses can be summarized as a complement, say **Conclusion 29-C:**

> Accident frequency and the total number of victims generally increase during the first six months--the third month, limit for legal abortions,[11] is the notable exception that resembles the ninth month--and fall during the last three months.

As an explanatory hypothesis, we developed **Conjecture 7** in [1, p. 149]:

> "An increased ratio of estrogen hormones to progesterone that is not compensated by a sufficient increase in androgen hormones reduces the ability to perform learned mechanical tasks."[12]

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[11] We studied in detail the series on abortion and found it to be highly correlated with the number of women in their third month of pregnancy and a little less with the number of women in their second month of pregnancy. The pattern of correlations suggested simultaneously that the seasonal conception pattern of women that would have an abortion was not different from that of those who would give birth and that the third month limit was quite respected.

[12] Formally, one could have a slightly more general formulation that would distinguish between the effect of levels and ratios of the various hormones.

In addition to explaining the results summarized in Table 1, this conjecture has the advantage of explaining British results [6] on the influence of drugs on the probability of accident. Oral contraceptives were found to be the category of drugs that most increased accident probability: they increased relative risk 5.6 times--sedatives and tranquilizers increased it 5.2 times and drugs in general 2.0 times. As oral contraceptives increase the ratio of estrogens to progestogens by much more than an order of magnitude[13] and create a state of permanent pregnancy, they should be expected to affect the performance of tasks. My conjecture, inspired by results obtained on rats [7], has relevance for the analysis and prevention of accidents in general. Further work might explore further the relationship between hormonal states in general--not only those modified by pregnancy and oral contraceptives--and accidents.

G. Impaired faculties

- Hours worked

The length of the work week (in manufacturing) reduces the total number of accidents but increases the number and severity of accidents with bodily damage. We do not know whether the resulting increase in the number of victims is due to uncompensated fatigue or to travelling outside of the peak hours.

- Drug consumption

Increased consumption of drugs increases all categories of accidents and victims despite a reduction in the morbidity rate.

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[13] We computed an average ratio of 33 for 24 brands available in 1978.

- Alcohol consumption

Table 1 also contains some of the results that led to new conclusions. **Conclusion 33** and **Conclusion 34** in [1, p. 181] respectively state:

> "[Whether one holds road use constant or allows for its variation,] increased aggregate alcohol consumption has no significant effect on the total number of accidents and on injuries, but reduces fatalities."
>
> "[Holding road use constant,] breaking down alcohol consumption by type shows that wine reduces all categories of accident, their severity and the number of victims. Only beer increases fatalities and reduces injuries: spirits and cider do the reverse."

To understand how aggregate alcohol consumption at prevailing levels could reduce the total number of road victims because of a strong decrease in fatalities, we develop a **Driver-Mix Conjecture** that could be stated as:

> "When aggregate consumption of alcohol increases from relatively low per capita levels, **the overwhelming majority [of drivers] drink a little, which reduces their risk below that prevailing when they do not drink**--perhaps because they compensate or are less aggressive; this reduction may more than offset the increase in risk for the minority [of drivers] who drink more heavily, depending on their relative proportions on the road."

In [1], we also start to review a number of past studies and find some that have results consistent with this conjecture--others have since come to our attention. We also find, in a simple subsidiary model of alcohol sales in Quebec that the breathalizer law of December 1969 *increased* alcohol sales by 4%. If this result is confirmed by further work, the breathalizer law achieved the first part of its effect by telling everyone how much they could safely drink, thereby causing the average driver to increase consumption up to that level, which reduced fatalities. But, holding alcohol consumption constant, the law also modified the drinking behaviour of some drivers, presumably reducing their consumption: this produced an offsetting increase in fatalities (not shown in Table 1). Score? Zero. The Lord works in indirect ways.

H. Trip purpose

Other results not shown in Table 1 indicate that the purpose of the trip, perhaps in conjunction with associated car occupancy rates, influences driving care--probably speed: in order of decreasing effect, work, shopping and vacation trips increase accident frequency and all categories of victims relatively to trips that are for some other purpose.

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